Vision quest

A radical theory seeks to overturn current views of how we see the world.

Why We See What We Do: An Empirical Theory of Vision
by Dale Purves & R. Beau Lotto
Sinauer Associates: 2002. 263 pp. $42.95, £27.99

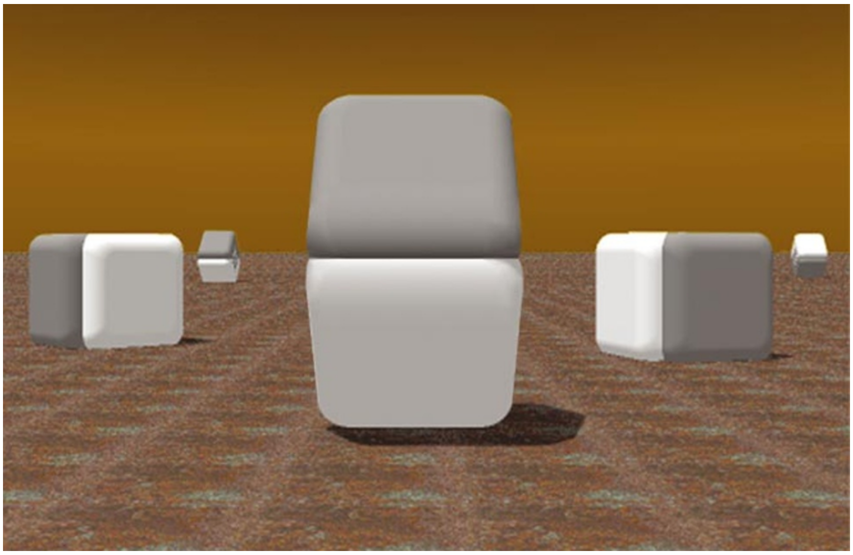
Michael Morgan

The standard model of vision, which this book ambitiously sets out to replace, begins with the retinal image being transduced into electrical signals by rods and cones. It is then analysed by banks of low-level sensors, such as retinal ganglion cells. To some extent these impose their own structures on the image, causing visual illusions such as Mach bands — the bright or dark regions perceived at the interface between bright and dark areas. The information transformed in this way is then used by higher-level mechanisms to infer the most likely structure of the outside world that caused the retinal images. This reconstruction can never be more than a best guess, however, because it is based on incomplete information from the two-dimensional image.

George Berkeley, in his *Essay Towards a New Theory of Vision* in 1709, thought the retinal image so unreliable that the true state of affairs had to be established by touch. The nineteenth-century physicist and physiologist Hermann von Helmholtz relented somewhat, and thought that the visual system could to some extent educate itself; he described vision as a process in which we infer the nature of the outside world from its images on the retina.

Fast forward to modern computational vision, as popularized by David Marr in his book *Vision* (W. H. Freeman, 1982), and we find that vision has been redefined. It is now described as an ill-posed mathematical problem (akin to deriving the number and speed of boats in a busy harbour from the ripples that they cause), but one that can generally be solved satisfactorily by making use of constraints derived from the most likely structure of the world.

Purves and Lotto will have none of it, except for the ambiguous nature of the retinal image, which is their starting proposition. Their 'empirical theory of vision' is that when we have a particular optical image on the retina, we experience a whole set of mental images with which it has been associated in the past, by either contiguity or similarity. We then have a perception that is some sort of combination of these images, either a mixture, a sum or a 'centroid' (it is not always clear which). At least, this is what I think they are saying. Perhaps the example of Mach bands will make the theory clear.



Seeing is believing: in the Cornsweet effect, the different brightness where the two central blocks meet creates the false impression that the rest of the lower block must be lighter than the upper block.

Mach bands arise at the extrema of linear luminance gradients, which we can think of as fuzzy shadows between bright and dark areas. On the bright side, observers see a thin white band; on the dark side they see a dark band. The Austrian physicist Ernst Mach deduced from this that some early filtering mechanism must be extracting the second derivative of the luminance profile, a guess later proved correct for retinal ganglion cells under appropriate conditions of illumination. Purves and Lotto show that these bands can also arise in real luminance profiles, such as those from the edge of a curved-edge cube lit from above and in shadow underneath. This is an interesting observation but doesn't explain why we see the bands when there are none in the image.

The crucial paragraph (and the pivotal section of the book) says, in part, this: "If the visual system evolved to see luminance relationships wholly on the basis of past experience … then the perceptual response elicited by the Mach stimulus will necessarily incorporate into the ensuing percept the relative contribution of the sources to similar and even more distantly related stimuli in the past, including, in proportion to their frequency of occurrence, the highlights and lowlights in the luminance gradients associated with curved surfaces."

I read this as saying that some linear luminance gradients have real Mach bands, and therefore, that all linear luminance gradients have some Mach bands. Because they are all similar? Because they are associated in temporal contiguity? The answer is not clear to me. What is sure, however, is that this is indeed a radical new theory. It has nothing to do with inferring the most likely nature of the outside object, as the bands are incidental features of illumination.

This impression is reinforced by analysis of the Chubb illusion, in which observers see a medium-contrast patch of texture apparently reduced in contrast when it is surrounded by texture with higher contrast. There is, as it happens, a plausible physiological explanation of this effect using lateral gain-control pathways in the visual cortex, but — as in the case of Mach bands, which are present in the output of retinal ganglion cells — Purves and Lotto have other ideas. The real explanation, they say, is that the image that evokes the Chubb illusion is similar to one that evokes the impression of translucence. They show that the Chubb illusion is abolished if the image is altered to make translucence a less likely interpretation. Our perception must therefore incorporate a little bit of translucence, making the low-contrast region of the image appear to have even lower contrast. This is the reverse of what we would expect from a reconstructionist theory such as that proposed by Helmholtz, according to which we would correct for the loss of transmission caused by translucence and see the patch more as it really is — as having higher contrast.

The sections of the book on brightness are the most interesting and challenging, with stunning illustrations and thought-provoking demonstrations. I found the other sections less compelling, particularly the bit about geometrical illusions such as the Müller–Lyer and Poggendorf effects. For example, the authors ignore Glass's suggestion that the latter effect is enhanced by optical blur, along with virtually all other relevant psychophysical work. In general, the book is much stronger on polemic than on hypothesis testing.

After reading the book, I wasn't sure that I had understood the theory, so perhaps I have not done it justice. The summary at the end talks of retinal stimuli triggering 'reflex responses' that have been learned over time. There have been several behavioural theories of perception: is this another? Concerning reflexes, it is interesting to think of the celebrated McCullough effect, in which prolonged inspection of tilted, coloured lines causes achromatic lines of the same (but no other) tilt to have the complimentary hue to the 'conditioning' colour. According to the 'empirical theory', shouldn't they have the same colour? Shouldn't the 'waterfall after-effect' go in the same direction as the bayesian-biasing waterfall? Perhaps the theory can be refuted after all. ■

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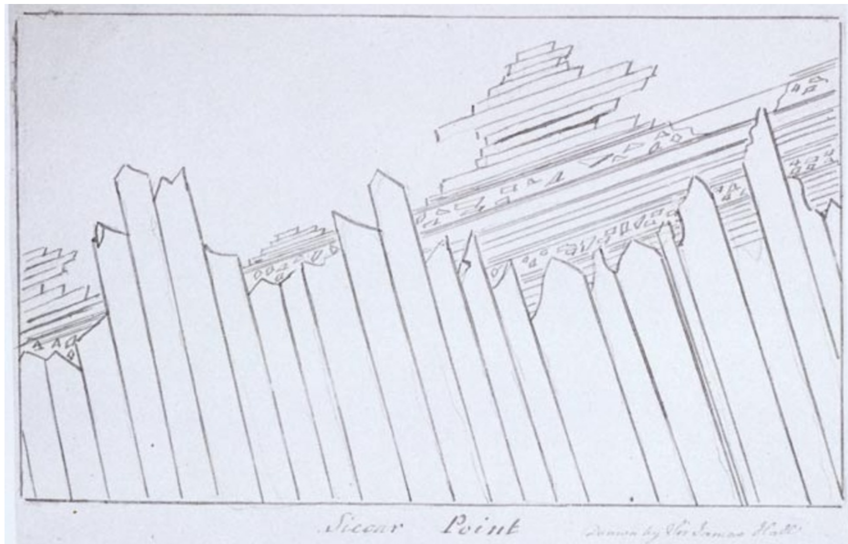
Discovering geological time

The Man Who Found Time: James Hutton and the Discovery of the Earth's Antiquity
by Jack Repcheck
Perseus: 2003. 229 pp. US$26, Can$40
Simon & Schuster: 2003. £15.99

David R. Oldroyd

The Man Who Found Time is an example of a genre of science history that frequently appears in airport bookshops. The author takes an important figure or theme in the history of science — often one little known to the general public — and writes about it in a pleasant and engaging way, telling a story that deserves to be widely known. Such books seemingly make good money for publishers and authors, and are likely to be reviewed widely in journals such as *Nature*. So it is surprising how few professional historians of science have grasped such attractive opportunities.

These 'airport lounge' books seem to be creatures of publishers as much as authors. But why do publishers choose amateur science historians as writers? Who has the idea for these books: the authors or the publishers? Who does the real work in getting these books out? These thoughts are prompted by Jack Repcheck's enormous list of acknowledgements, among whom the agent, the publisher's staff and the editor are given special thanks. Repcheck also thanks various Hutton scholars for doing "research and spadework" without which the book "would have been impossible".



J. D. CLERK/SCRAN

Rock solid: drawings of Siccar Point support James Hutton's ideas about the vastness of geological time.

With all that back-up, one might expect a superior product. However, I was initially provided with a pre-publication version of the book. This gave me an insight into the author's uncertain grasp of the facts. The early copy was littered with so many errors that I asked to be supplied with the final version of the book before attempting a review. When it arrived, I was pleased to see that many of the obvious glitches had been dealt with (for example, Derby was now a town and not a river). But the principle of universal gravitation was still described as "the first natural law to be identified" (what about the laws of reflection and refraction?). Some erroneous definitions of geological terms had been corrected, but incongruities remained, such as the idea of "vacillation" between marine and terrestrial environments.

Having said this, the theme is worthwhile and the text is pleasantly written. After an (unnecessarily lengthy) account of how the idea of a young Earth was established, based on biblical and other historical records, Repcheck sketches some of the main events of Scottish eighteenth-century political history, Hutton's Edinburgh environment, his intellectual milieu, and his personality, career, ideas and achievements. He then gives an incomplete account of Hutton's scientific work, and carries the story through to the work of Charles Lyell and Darwin.

Naturally, I accept that Hutton was a pivotal figure in the history of geoscience and deserves to be much more widely known. He considered weathering and erosion, and developed a cyclic theory of Earth's history. Sediments were thought to be consolidated by the Earth's hypothesized internal heat. From time to time, magma was supposedly intruded into the Earth's crust, elevating land and forming new rock that in time would weather and erode to form new soils and eventually sediments. So while constantly changing, the Earth is a grand system in which the formation and destruction of rocks is balanced and conditions suitable for human existence maintained.

Hutton predicted the occurrence of unconformities, and confirmed his predictions in the field. When he examined a remarkable unconformity on the Berwickshire coast (at Siccar Point) with friends, they felt they were looking into the "abyss of time". The immensity of time that Hutton's grand cycles of geological change required could be seen from the arrangement of the rocks. Without such work, Lyell and Darwin would not have been able to do what they did.

Repcheck outlines this argument satisfactorily, but there are serious gaps in his account. No mention is made of Hutton's work on philosophy or his unpublished treatise on agriculture (which adumbrated the idea of natural selection). Repcheck insists on the significance of Hutton's chemical ideas, but says nothing about his ideas on phlogiston and 'solar substance', which were important in his overall theory (to the extent that some Gaia aficionados regard him as one of their forebears). Little is said about Hutton's methodology, and there is nothing about his claimed intellectual debt to the earlier work of Robert Hooke (described in Ellen Drake's 1996 book *Restless Genius*), other than saying that Hooke's work offered one of the important precursory publications for Hutton.

More seriously, there is no mention of how Lyell's observations of the still-standing columns of an ancient building at Pozzuoli in the Bay of Naples influenced Lyell's ideas about elevation and subsidence. Even more